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Large Gas Disks in Radiogalaxies

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Abstract.
Large-scale (up to 100 kpc) H I structures have been found in three radio galaxies using the WSRT and the VLA. In one case, the H I has been detected in emission while in the other two H I absorption is detected against the radio lobes. In at least two of the three studied radio galaxies the H I appears to be distributed in a large disk and the large amount of neutral gas detected ($\gtrsim 10^9$ $M_\odot$) indicates that it is resulting from mergers of gas-rich galaxies. The relatively regular structure and kinematics of these disks suggest that the merger must have happened more than 10^8 yrs ago, therefore supporting the idea that the radio activity starts late after the merger. In these low redshift radio galaxies we may witness the processes that are more efficiently and frequently happening at high-z.

1. Introduction

There exists compelling morphological and kinematical evidence that the activity in powerful radio galaxies is triggered by galaxy mergers and interactions. This is also supported by the theoretical results (Kauffmann & Haehnelt 2000) that the evolution of supermassive black holes is strongly linked to the hierarchical build-up of galaxies. Although these processes are likely to be more efficient and frequent at high redshifts, they are observed also in relatively "nearby" radio galaxies. However, considerable uncertainties remain about the nature of the triggering events. Outstanding questions include: 1) is the activity triggered by major mergers between gas-rich galaxies or by minor accretions events? 2) what is the relationship with other types of merging systems such as ULIRGs? 3) at what stage of the merger do the jets and associated activity occur? 4) do all giant elliptical galaxies go through a radio phase as they evolve via galaxy interactions?

It is now clear that some early-type galaxies contain a large amount of H I, in some cases even 10^{10} $M_\odot$ (e.g. Oosterloo et al, 2001 and ref. therein). This

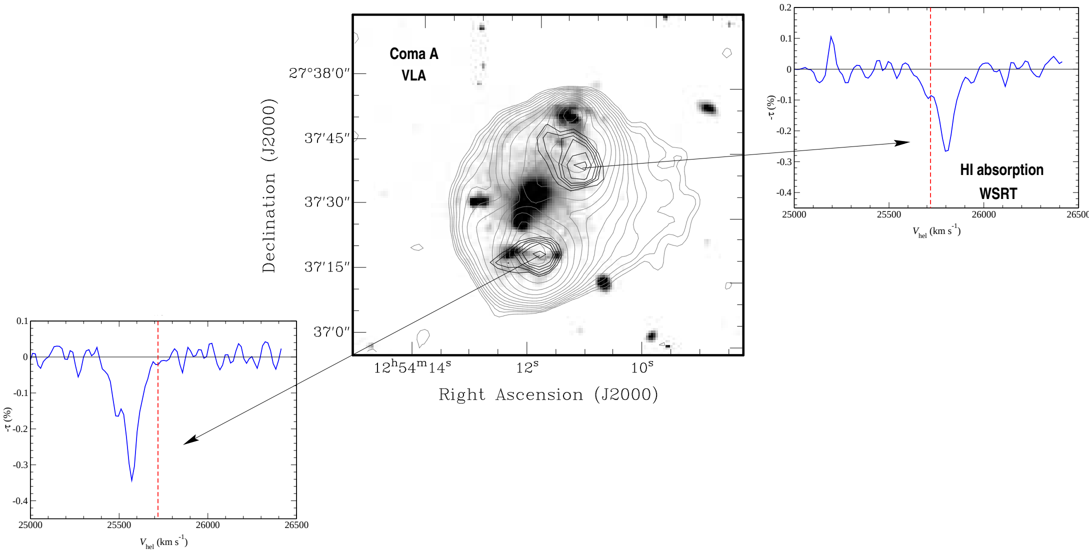

Figure 1. Hα image (grey scale) of Coma A (from Tadhunter et al. 2000) with superimposed contours of a 20-cm continuum image (about 1″ resolution, from van Breugel et al. 1985). The dark contours represent the region where H I absorption has been detected. The profiles of the optical depth (τ) of the H I absorption against the two radio lobes.

gas is an important element for understanding the origin and the evolution of these galaxies. Large tails/arms of neutral hydrogen are a prototypical signature of a recent merger, while gas settled in large disk-like structures may indicate an older merger. If radio galaxies have a similar origin, we may expect to find also there such H I signatures. The H I properties could allow us to understand the temporal sequence between merger, starburst phase and onset of the radio activity. It is, therefore, important to make the connection between the presence of a rich ISM, the radio galaxies and the evolution of the population of giant elliptical galaxies in general. The detection of H I around radio galaxies would therefore give a powerful tool to answer some of the above questions.

2. Radiogalaxies with extended H I disks

So far we have found three radio galaxies where the neutral hydrogen is detected at large distances from the nucleus. An other possible candidate is the radio galaxy 3C 234 studied by Pihlström (2001).

2.1. Coma A

Coma A ($z = 0.08579$) has a spectacular system of interlocking arcs and filaments detected in optical emission lines (see Fig. 1 and Tadhunter et al. 2000 for details). This ionised gas and the radio structure show a striking match that is suggestive of a complex interaction between the radio structure and a

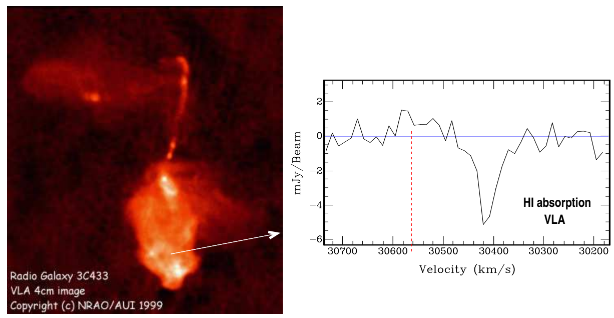

Figure 2. (*Left*) Continuum image of 3C 433 (from Black et al. 1992) and H I absorption profile (*Right*). The systemic velocity is indicated.

rich interstellar medium. Using the WSRT and the VLA we have detected H I absorption in front of both radio lobes of Coma A (see Fig. 1 and Morganti et al. 2001). This is a rare case where the absorption is not detected against the nuclear regions of a radio galaxy, but it is situated at large distances (30 kpc) from the centre. The kinematics of the neutral and ionised gas suggests that they are part of the same structure, likely a large-scale disk with the radio lobes expanding into this disk.

2.2. 3C 433

3C 433 is a radio galaxy ($z = 0.1016$) with an unusual double-lobed radio morphology (see Fig. 3). We have observed 3C 433 using the VLA (C-array) and we have found that at least part of the H I absorption (originally detected with the Arecibo telescope, Mirabel 1989) is situated against the southern radio lobe at about 40 kpc from the nucleus (see Fig. 2). The optical depth of the absorption is only about 2%. Unlike Coma A, no ionised gas has been detected near the location of the H I absorption. 3C 433 is a far-IR bright radio galaxy with a young stellar population component (Wills et al. 2001). The presence of large-scale neutral hydrogen could be related to the particular stage of the evolution of this radio galaxy. 3C 433 is perhaps a relatively young radio galaxy.

2.3. B2 0648+27

B2 0648+27 ($z = 0.041$) is a compact radio galaxy and in this object we have detected neutral gas both in emission and in absorption (see Fig. 3, WSRT observations). The neutral gas is in a disk-like structure of about 100 kpc in size and contains about 10^{10} $M_\odot$ of H I. Such a large amount of gas is usually believed to originate from a "major merger", i.e. a merger of two large disk galaxies. Like 3C 433, B2 0648+27 is a far-IR bright galaxy with a young stellar population component. The relatively regular kinematics of the gas indicates that the merger must have happened more than 10^8 yrs ago and therefore the radio activity (usually estimated to last for few time 10^7 yrs) appeared at a late stage in the merger. H I in absorption is detected only in the centre, where the radio continuum is present, and has a kinematics similar to the molecular gas detected, in large amounts, in this object (Mazzarella 1996).

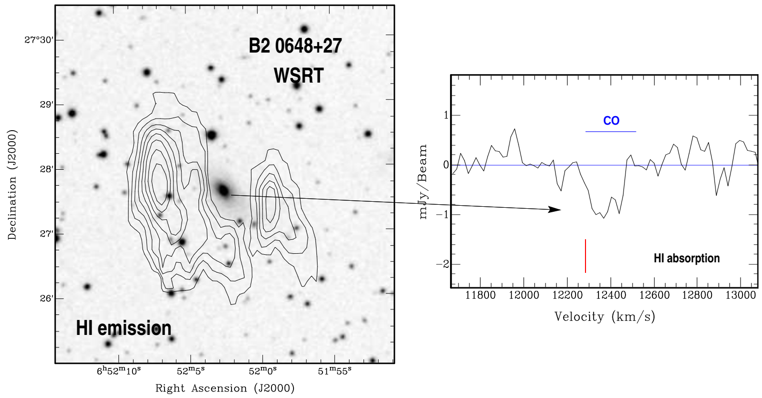

Figure 3. (*Left*) H I total intensity contour of the radio galaxy B2 0648+27 superimposed on to an optical image. (*Right*) H I absorption profile (the optical systemic velocity is marked). The range of the CO emission (from Mazzarella et al. 1993) is also indicated.

3. Summary

Large-scale (up to 100 kpc) gas structures have been found in three radio galaxies and they can be used to understand the origin and the evolution of these systems. The presence of a young stellar population component in two of these objects will give further constrains on type and age of the merger. Extended H I absorption (observed against the Lyα emission) has been found in a high fraction of high-z radio galaxies (van Ojik et al. 1997). This is considered an indication that high-z radio galaxies are located in dense environments and helps in probing the effects of radio jet propagation in this medium. Although this may be happening more efficiently and frequently at high redshifts, in the low redshift radio galaxies described here we may witness a similar situation. However, in the low redshift galaxies, we will be able to investigate in much more detail the relation between the thermal and non-thermal gas.

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